

APPENDIX A

PROJECTS AND METHODS STUDY OVERVIEW



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APPENDIX A PROJECTS AND METHODS STUDY OVERVIEW

The State and YWG Basin has conducted a series of recent studies to develop a better understanding of their consumptive, environmental and recreational needs in the basin. The BIP draws from these planning efforts to provide a comprehensive overview of the YWG Basin's current and future water needs and the actions necessary to meet such needs. This appendix introduces the previous studies conducted and provides a comprehensive overview of the P&M Study, which is the most recent study conducted by the YWG Basin and the primary study used to inform the BIP.

A.1 Overview of YWG Studies

Table A-1 provides a summary of the basin-wide studies conducted for the YWG Basin since the initial SWSI in 2003. These studies encompass assessments of current and future M&I, energy, agriculture, environmental and recreational needs, and the modeling exercises conducted to evaluate water supply shortages, future water supply projects, climate change and impacts to instream flows.

Table A-1 Previous Studies

| Year Study Completed | Study | Summary |
|----------------------|--|---|
| 2004 | SWSI | Identified Colorado's current and future water needs and examined a variety of approaches Colorado could take to meet those needs. SWSI implemented a collaborative approach to water resource issues by establishing SWSI roundtables. SWSI focused on using a common technical basis for identifying and quantifying water needs and issues. |
| 2008 | Energy Development Water Needs Assessment Phase I | Developed future demand estimates through the 2050 planning horizon for the oil shale, natural gas, coal, and uranium energy sectors. |
| 2010 | Updated SWSI | Updated the original SWSI to include new data and develop projections through a future planning horizon of 2050. |
| 2010 | Nonconsumptive Needs Focus Mapping Report | Development of environmental and recreational focus maps and attribute tables to further characterize the environmental and recreational needs within the State's Basins. |
| 2011 | Basin Needs Assessments | Summarizes information developed through the SWSI process for the YWG Basin. |
| 2011 | Energy Development Water Needs Assessment Phase II | Updated the oil shale demand from the Phase 1 Energy Development Water Needs Assessment. |
| 2011 | Yampa/White Agricultural Water Needs Assessment Report | Refined and updated previous estimates of current agricultural uses and supplies, evaluated future agricultural demands, assessed climate change and energy development sector impacts on agricultural water availability, and developed alternatives to satisfy shortages. |
| 2012 | Colorado River Water Availability Study | Provides a common platform to determine consumptive and nonconsumptive uses throughout the western slope. StateMod models developed under the CDSS for the Colorado River main stem, Gunnison River, Dolores/San Juan/San Miguel Rivers, and the YWG Rivers were used in the development process. Current demands, operations, and historical hydrology as well as a suite of climate change demands and hydrologies were used to determine the current and potential future state of water availability along the western slope of Colorado. |



| Year Study Completed | Study | Summary |
|----------------------|---|---|
| 2012 | Yampa-White Basin Roundtable Watershed Flow Evaluation Tool Study | Applied ecology-flow metrics to identify environmentally and recreationally significant areas and determine the risk levels associated with those areas. The associated risk metrics characterize the impacts of increased water use within the basin on trout, warm water fish, cottonwoods and boating. |
| 2013 | CWCB Nonconsumptive Use Toolbox | Provides a framework to evaluate existing information and identify opportunities and challenges regarding implementation of environmental and recreational projects. |
| 2014 | YWG Projects and Methods Study (Draft Final February 27, 2014) | Evaluates the M&I, energy, agricultural and environmental and recreational needs and shortages in the YWG Basin using the StateMod model. |
| 2014 | Yampa Basin Alternative Agricultural Water Transfer Methods Study | Identified several locations where alternative agricultural transfer methods meeting the needs of both the environment and consumptive uses could be implemented. These temporary water leasing arrangements could offer substantial benefit to both consumptive and nonconsumptive interests if their associated challenges can be overcome. |
| 2014 | Energy Development Water Needs Assessment Update Phase III | Assess current and projected energy water demands provided in the Phase I and Phase II Energy Development Water Needs Assessment. Where appropriate, estimates will be revised to reflect the most up-to-date data trends. Emphasis is placed on updating the natural gas and oil shale demands. |

A.2 Introduction to the P&M Study

The P&M Study was the primary study used to inform the BIP regarding future water supplies, demands, and shortages including projections of demands and alternative hydrologic conditions. It was conducted by the YWG BRT to:

- Develop a common understanding of consumptive, recreational and environmental water needs in the Yampa-White Basin.
- Analyze river operations of the Yampa and White Basins, including alternative model scenarios.
- Evaluate water right priorities of Statewide SWSI Alternatives relative to those of the YWG Basin.

The study used the StateMod modeling platform which is Colorado's water allocation model maintained by CDSS. StateMod is the water allocation model in CDSS that is used for the primary purpose of modeling water rights and allocating water to those rights. StateMod uses strict prior appropriations (i.e., first in time, first in right) to model diversions. The model was initially developed in 1994 and has been continually updated as new studies and data becomes available. The 2009 release for both the Yampa and White basins were used for this study. The model uses a monthly time-step. A variety of previous studies were used to inform the modeling effort.

The P&M Study evaluated baseline conditions and six modeling scenarios. As shown in Figure A-1, these scenarios consist of a combination of demands, hydrology and the presence of IPPs. The demand inputs include the current and future 2050 water needs for the M&I, energy, agriculture, environment and recreation sectors at specific modeling nodes in the StateMod model. Information on how the demands were developed for each of these sectors is summarized below. The P&M Study results present the average annual water shortages or flow risks at each of the respective StateMod nodes and for each of the sectors both in tables and spatial figures.



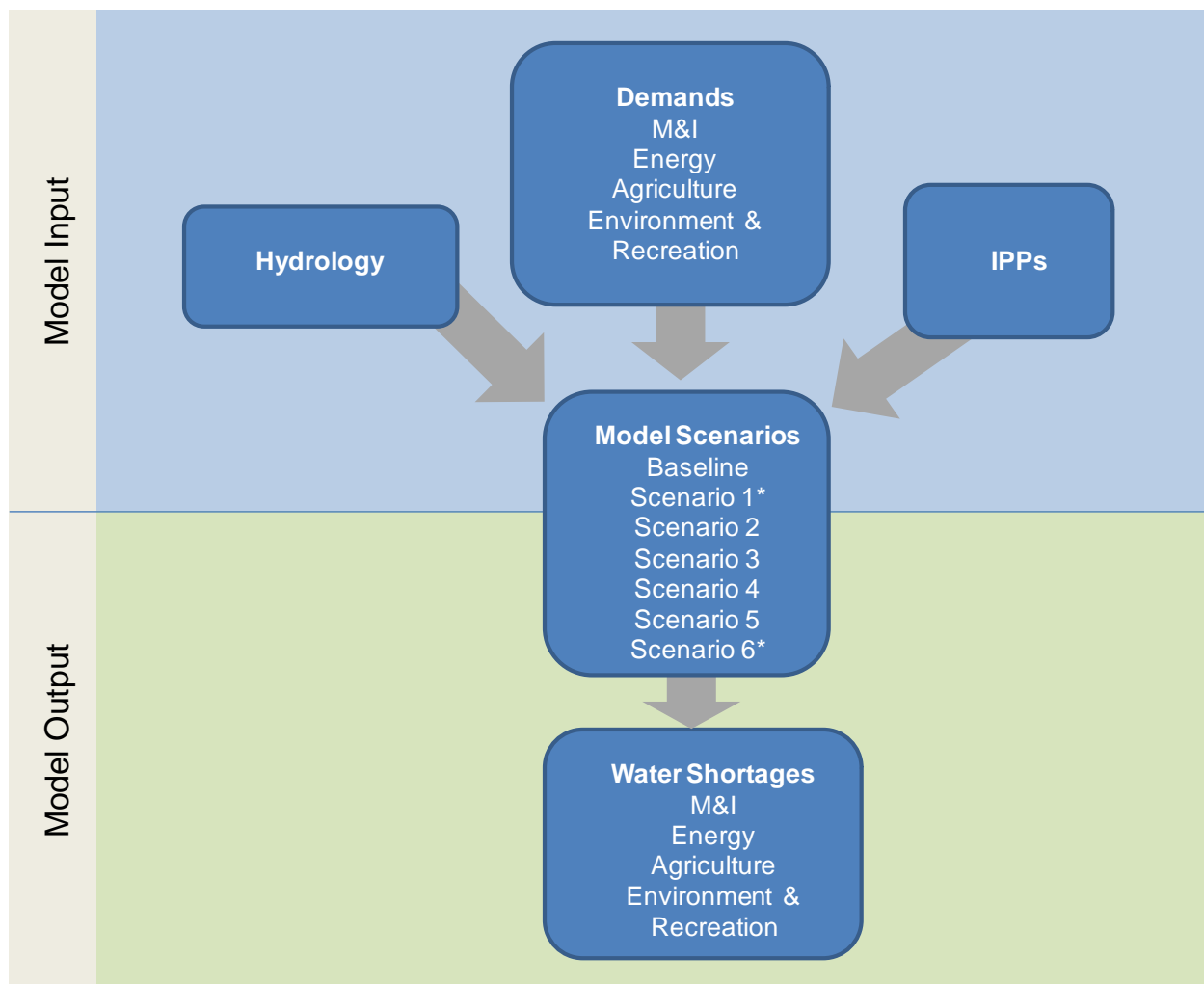


Figure A-1 Elements of the Model Scenarios

Table A-2 shows the elements for each of the respective scenarios. The modeled baseline (current) represents current conditions and operations. This includes all existing reservoirs, water rights, imports, diversions, and return flows while incorporating the historical hydrology and climate over the period 1950 through 2005. It provides a means to compare the other scenarios (e.g., supply projects, climate change, new demands, etc.). Scenarios 1, 2, and 3 were selected during the July 17, 2013 YWG BRT technical subcommittee meeting. Scenarios 4, 5, and 6 were selected after the results from the first three scenarios were presented during the October 3, 2013 YWG BRT subcommittee meeting. These scenarios incorporate a range of demands, hydrology types and means to assess the implications of whether new IPPs are implemented.

Table A-2 Model Scenarios

| BIP Scenario | Nomenclature in the P&M Study | Hydrology | Demands | IPPs |
|-------------------------|-------------------------------|------------|------------------|-------------------|
| Baseline | Baseline | Historical | Existing demands | No IPPs Selected |
| Dry Future IPP Scenario | Scenario 1 | Dry | High | All IPPs Selected |
| Dry Future Scenario | Scenario 6 | Dry | High | No IPPs Selected |



The baseline condition and Dry Future IPP Scenario and Dry Future Scenario were selected for further evaluation in the BIP. These scenarios entail high demands and the dry hydrology which provides a conservative planning framework to best guarantee that the YWG Basin can meet their future water needs. The remainder of this appendix provides detailed information on the demands, hydrology and IPPs used in both the P&M Study and BIP.

A.3 Hydrology

Three 56-year sequences of climate adjusted hydrology (based on the historical records from 1950 to 2005) were selected for both the Yampa and White Basin StateMod P&M modeling effort. The CRWAS final report provides details on the development of these hydrology sequences. The hydrology sequences were selected from seven of the original ten climate change hydrology scenarios used in the CRWAS study.^{1,2} For both the Yampa and White Basins, a wet, average and dry-year hydrology was selected for simulation using the YWG Basin's StateMod models. These three hydrology sequences represent the following scenarios:

- Wet hydrology - more water exists in the future than historically
- Average hydrology - average annual flows most similar to historical flows
- Dry hydrology - less water exists in the future than historically.

The hydrology sequences were selected based on the mean annual volume of water at the Maybell (USGS ID 09304500) and Meeker (USGS ID 09251000) gages for the Yampa and White Basins, respectively. The hydrology with the greatest volume of water was selected as the wet hydrology, the hydrology with the smallest total volume was selected as the dry hydrology and the hydrology closest to historical conditions was selected as the average hydrology.

A.4 Sector Demands and Shortages

A.4.1 M&I

Baseline and Future Needs

The YWG Basin BIP Subcommittee chose the high demand, low supply scenario from the P&M Study to be analyzed for the BIP. Table A-3 presents the SWSI 2010 and Basin Needs Assessment Report county-level M&I population and needs for baseline conditions and the future high demand level which reflects expected increases in population. The high economic growth scenario includes a 550,000 barrel per day oil shale industry; therefore, the population in the YWG Basin is expected to more than triple by the year 2050 under this scenario.

Table A-3 Baseline and Future M&I Demands

| County | Baseline Population | Baseline Water Demand (AFY) 2008 | Future Population 2050 High | Water Demand with Passive Conservation (AFY) 2050 High |
|--------------|---------------------|----------------------------------|-----------------------------|--|
| Moffat | 14,600 | 3,200 | 31,000 | 6,400 |
| Rio Blanco | 6,700 | 2,000 | 59,000 | 17,000 |
| Routt | 23,800 | 6,500 | 63,000 | 16,000 |
| Total | 45,100 | 12,000 | 153,000 | 39,000 |

Source: Yampa-White Basin Needs Assessment Report, 2011; SWSI, 2010

¹ This did not include paleo records because such records were not available for the White River.

² CRWAS, 2012



To evaluate baseline conditions and the six modeling scenarios for M&I demands in StateMod, the P&M Study took these county-level demands projected out to 2050 and applied them to specific model nodes using a variety of methods depending upon data availability. In general, the follow approach was taken:

- Major M&I demand areas: demands and water rights, historical use and reservoir data for population centers were explicitly modeled , e.g., Craig
- Minor M&I demand areas: demands were aggregated together for the entire basin into one location, e.g., existing M&I demand for Water District 55 (Little Snake River) was grouped and modeled on the Little Snake River in Moffat County (55_AMY003)

This methodology resulted in 9 aggregate M&I nodes in the YWG Basin as shown in Table A-4.

Table A-4 Node-based M&I Demand Locations

| Diversion Name | Basin/Stream (Water District) |
|--|-------------------------------|
| | Moffat County |
| Craig Water Supply Plant (440581) | Lower Yampa (44) |
| District 44 Aggregate Existing M&I (44_AMY001) | Lower Yampa (44) |
| District 55 Aggregate Existing M&I (55_AMY003) | Little Snake (55) |
| | Rio Blanco County |
| Rangely Water (430889) | White (43) |
| Meeker Demand (950810) | White (43) |
| District 43 Aggregate Existing M&I (43_AMW001) | White (43) |
| | Routt County |
| District 57 Aggregate Existing M&I (above Craig) (57_AMY001) | Middle Yampa (57) |
| District 58 Aggregate Existing M&I (Steamboat Springs) (58_AMY001) | Upper Yampa (58) |
| Fish Creek Municipal Intake (580642) | Upper Yampa (58) |

Source: P&M Study, 2014

To represent baseline conditions on a monthly basis, the P&M Study indicates it used a 12-month demand pattern reflecting average demands from historical periods, e.g., demands from the Town of Craig are averaged over the period 1999 to 2004. However, it is not clear how this approach relates to the SWSI 2010 and the Basin Needs Assessment Report data, or if demands for other M&I nodes were developed from other historical periods. To evaluate future consumptive M&I demands for 2050, low, medium, and high demands were split up by county into their respective existing M&I demand nodes. A “driver multiplied rate of use” approach was used to develop the low, medium and high demands which considered factors from SWSI such as job growth and estimated population. Node demands were scaled up in proportion to the projected growth of basin-wide, or county-wide demands. An example of this scaling approach is provided in Table A-5.

Table A-5 Example of Scaling Approach to Develop Future M&I Demands by Node

| Node | Baseline Demands (AFY) | Future Demands* (AFY) |
|------|------------------------|-----------------------|
| 1 | 100 | 200 |
| 2 | 900 | 1,800 |

*Future total county demands = 2,000 AFY (node 1 = 10% or 200 AFY; node 2 = 90% or 1,800 AFY)



The future M&I demand estimates include passive conservation which mainly reflects water demand reductions due to policy measures such as those requiring manufacture of more efficient toilets, washing machines and dishwashers and the subsequent installation, or retrofit, of these appliances into existing housing and commercial buildings.

Shortages

Future M&I shortages are evaluated in the BIP by assessing the Dry Future IPP and Dry Future Scenarios which both reflect high demand, low water supply scenarios. The results for the updated BIP modeling effort are presented Chapter 3.. The IPPs presented in the P&M Study do not include augmentation for existing M&I demands.

A.4.2 SSI

Similar to previous reports, the P&M Study evaluated consumptive water demands for thermoelectric power generation and energy development separately. However, it did not evaluate large industrial as a separate category as previous reports have. A discussion for each of these categories follows based on results from the P&M Study.

Thermoelectric Power Generation

Baseline and Future Needs

Since thermoelectric power demands are related to needs of the population served, it will trend in a similar manner to changes in population, i.e., M&I demands. The BIP presents the high demand, low supply scenario results from the P&M Study.

Using a methodology similar to the M&I demands, thermoelectric power generation demands were modeled explicitly in the P&M Study by representing each existing thermoelectric power generation facility - Craig Station in Moffat County and Hayden Plant in Routt County - as a specific model node. All thermoelectric demand for Moffat County was applied to Craig Station and similarly all demand for Routt County applied to Hayden Plant since only one plant exists in each county. Consequently, this approach assumes these facilities will meet all future power generation needs and that no new plants will be required. Both plants have redundant water supplies in addition to their more junior water rights with in the form of releases from Steamboat Lake (Hayden Plant), Stagecoach Reservoir (Craig Station), and Elkhead Reservoir (Craig Station), and since no flows return back to the stream, both plants are modeled as fully consumptive.

Since Craig Station has three units that are supplied by both Stagecoach Reservoir (unit 1) and Elkhead Reservoir (units 1 and 2), the P&M Study modeling effort split Craig Station into two separate nodes; one representing units 1 and 2 and the other representing unit 3. This was done due to limitations with the model in order to accurately reflect the even split in demand that each unit has, i.e., each unit comprises one-third of the total Craig Station demand. In the model, Elkhead Reservoir makes releases to the first node with two-thirds of the demand (units 1 and 2) and Stagecoach Reservoir makes releases to the second node with one-third of the demand (unit 1).

Shortages

To evaluate future shortages, the Dry Future IPP and Dry Future Scenarios model thermoelectric power generation demand using redundant water supplies from Steamboat Lake for the Hayden Plant and Elkhead and Stagecoach Reservoirs for Craig Station. Updated modeling results for the BIP are presented in Chapter 3.



Energy Development

Baseline and Future Needs

The potential for energy resource development in northwest Colorado has driven specific studies to be completed to analyze the baseline and future water requirements of the industry. As mentioned in Chapter 2, three phases of the Energy Development Water Needs Assessment have been completed. Water needs related to the coal, oil shale, natural gas and uranium mining energy sectors have been developed for the following three components:

- Direct Water Demands: include the water required for the construction, operation, production, and reclamation needed to support the energy extractions and development processes
- Indirect Water Demands: water demands that result from the increase in the region's population due to the energy development and production
- Thermoelectric Power Generation Demands: energy development direct water demands are tied closely to increases in thermoelectric power generation demands, i.e., increased mining typically requires an increase in electrical needs and subsequently an increase in thermoelectric power generation water demands.

Indirect water demands have already been considered in the M&I demands discussed above from SWSI 2010 and the Basin Needs Assessment Report because they reflect the demands associated with an area's population, i.e., population growth directly attributable to the energy sector workforce. Similarly, the related impact on thermoelectric power generation demands due to increased energy workforce population are included in the demands for Craig Station and the Hayden Plant. Direct water demands associated with energy demand are in a separate category and were evaluated in Phase I and II of the Energy Development Water Needs Assessments. Phase II continued the work performed in Phase I of the study and calculated low, medium, and high demand projections for short-term, mid-term, and long-term planning horizons.

The recently completed Energy Development Water Needs Assessment Study Phase III reviewed and updated the direct water uses for energy development. The Phase III study carries forward the Phase I water use estimates for the coal and uranium sectors (because there is no new information or development prospects in those sectors) and updates water use estimates for the oil shale and oil and gas sectors. Since the Phase II report was published, both Chevron and Shell have ended their oil shale research projects in Colorado. The National Oil Shale Association markedly reduced water use estimates mainly because the large in situ projects proposed by Chevron and Shell were discontinued. Therefore, the Phase III reports new water use estimates for oil shale. Additionally, the Phase III report updates the direct water uses associated with oil and gas well drilling and completions since new information on drilling activity and resource development planning is available since 2008.

Natural Gas

The majority of natural gas related water demands are due to the hydraulic fracturing process (fracking). However, the P&M Study indicates that because water for fracking is typically sourced from areas that would not affect existing or future direct diversions, e.g., water from another state, leased or purchased irrigation water, treated or raw water leased or purchased from a municipal water provider, etc., water demands related to natural gas production was not included in the P&M Study. Further, the process only occurs at the beginning of natural gas well installation; therefore permanent water rights are not necessary. However, water supplies for drilling and well completion will in part be sourced via direct diversions. The Energy Development Water Needs Assessment Phase III updated the natural gas estimates and added additional oil demands.

Uranium

Coupled with small water demands even at the high production level and uncertain future locations, uranium mining was not included in the P&M Study or updated BIP modeling.



Coal

Water demands associated with coal mining are difficult to estimate because they are economically driven and therefore may occur in varying levels at existing locations or at a completely new location. As a result, locations for coal development were indistinct in the Energy Development Water Needs Assessment. More refined information was since made available, and subsequently used in the P&M Study, in the Peabody-Trout Creek Project Study. This study evaluated a water supply project on Trout Creek upstream of the confluence with the Yampa River to help Peabody Energy meet 6,000 AFY of energy development demands as part of the Peabody-Trout Creek Project³.

Oil Shale

The Phase II Energy Development Water Needs Assessment focused on the supply availability of oil shale development, with production mainly occurring in the Piceance Creek area in the White Basin. For the 110,000 AFY demand level for the high production scenario, Piceance Creek cannot reliably provide enough water to consistently meet the demand. As a result, water would need to be sourced elsewhere, including from storage and undecreed water right diversions. Three StateMod water allocation modeling scenarios were developed as part of the Phase II study to determine feasible supply options and are discussed further in the IPP section below.

Recently, the certainty of oil shale development in northwest Colorado has changed with research activities slowing and even completely stopping, e.g., Shell Energy in Rio Blanco County. Due to the lower likelihood that an oil shale industry will develop in the area, at least at the previously projected level, the Energy Development Water Needs Assessment Phase III updated the oil shale water demands.

Shortages

The P&M Study and updated BIP modeling does not assess shortages to the energy development industry.

A.4.3 Agriculture

Irrigation Demands

The YWG Basin's P&M Study and Agricultural Water Needs Study relied upon the same estimates of irrigation demands in the YWG Basin. The irrigation demands were developed using the CDSS 1993 coverage,⁴ historical diversion data and the CDSS consumptive use model called StateCU. Groundwater use for irrigation is relatively minor when compared to surface water diversions in the YWG Basin and is not considered in the modeling. The StateCU model was used to estimate the IWR using the modified Blaney-Criddle method. For application with StateMod, the IWR was divided by the irrigation efficiency corresponding to each respective diversion structure (i.e. model node) to determine the irrigation water demand diverted from the stream at the diversion structure.^{5,6} The irrigation water efficiencies were limited to a minimum of 30 percent and a maximum of 50 percent which were assumed to be reasonable efficiencies in the rugged mountain environment. This approach allows IWR to drive demands instead of historical diversions and enables various levels of irrigation demands to be modeled. The

³ It is being clarified how these demands were modeled and if they are in addition to those scaled up from SWSI 2010.

⁴ The State of Colorado developed a year 2000 irrigated acreage coverage, but CWCB staff indicated that this coverage is not as reliable as the 1993 coverage and recommended using only the 1993 acreage (meeting with CWCB staff, May 2009). Additionally, a 2005 irrigated acreage coverage has also been developed by CWCB, however, since the period of record of the study ends in 2005, this coverage has not been included in the CDSS models at the time of this study.

⁵ Average monthly structure efficiencies were calculated using the baseline scenario where the diversion structure efficiencies equaled the historical IWR divided by the historical water demand at the diversion structure ($IWR/Demand_{historical}$).

⁶ The irrigation demands for the baseline scenario were calculated as the maximum of the recorded historical diversion at the diversion structure or the StateCU generated IWR divided by the irrigation efficiency. Irrigation demands for all other scenarios were simply based on the IWR divided by efficiency.



irrigation demands presented in Chapter 2 of the BIP represent the irrigation demands at the diversion structure/model node.

For StateMod modeling purposes, the P&M Study used 43 nodes to represent all of the agricultural demands in the YWG Basin. Diversions greater than 5 cfs in the Yampa and 4.8 cfs in the White, were explicitly modeled. Diversions with decreed rates less than the aforementioned rates were aggregated with other diversions of a similar rate that were in the same drainage upstream of the nearest baseflow node. Nodes were also disaggregated where necessary to differentiate diversions specifically located on a modeled stream (A- aggregates) and tributaries (B- aggregates) to the modeled stream. Conceptually the irrigation demand at the B-aggregate nodes is limited to the amount of water physically available in the tributary. For purposes of modeling, this was assumed to be the maximum historical diversions at these nodes. Therefore it was assumed that the irrigation demands at the B-aggregates could not exceed the historical diversions at each respective node.

The high demand scenarios (Dry Future IPP and Dry Future) include the development of 14,805 acres of irrigation land on the Oxbow of the Yampa River. The oxbow diversions were treated as an aggregated agricultural diversion at the downstream end of the modeled reach with a 2013 junior water right.⁷ These additional demands were estimated using the StateCU model. However, the SWSI estimates of irrigation reductions discussed in Section 2.3.2, were not included in the P&M Study, given the uncertainty on the magnitude and location of reductions. Such estimates include a reduction of 1,000 to 2,000 acres as a result of urbanization in 2050 and a reduction in 3,000 to 64,000 acres due to transfers to address the M&I gap.

The StateCU and StateMod models were refined to include the Denver Water High Altitude crop coefficients for pasture grass/hay fields above 6,500 feet. In order to be consistent with CRWAS and common State Engineer Office practices, an elevation adjustment of 10% per 1,000 meters above sea level was made for all crops. When compared to previous SWSI IWR estimates, the IWR requirement increased by 54 percent basin-wide when the high –altitude coefficient for the grass/hay was included and by 65% when the elevation adjustment and high altitude crops were incorporated.

Irrigation Shortages

StateMod calculates the following types of irrigation shortages:

- Total/diversion shortages (at the headgate) - Difference between the irrigation demand at the diversion structure (model node) and the amount of water physically and legally available in the stream.
- Consumptive use shortage at the place-of- use - Difference between IWR and the amount of water actually diverted and multiplied by the diversion's maximum application efficiency. This represents the difference between the amount of water required to meet the crop irrigation requirement and the amount of water delivered to the crops.

For purposes of this BIP, the shortages are reported at the diversion point on the stream as opposed to the P&M Study which presented the shortages at the place-of-use. These shortages include losses and inefficiencies incurred from the point of diversion to the user end use. This provides a more direct means in evaluating the need for new IPPs by showing the demand/shortage directly incurred on the stream.

⁷ The Agricultural Water Needs Study modeled the base flows resulting from existing irrigation and storage as senior to any new water rights for diversions to supply this expanded acreage (p. 5-28). This modeling was consistent with the hydrologic analysis for the Yampa PBO that relied on the continued availability of such existing base flows in setting the targets at the Maybell gage with access to only 7,000 AF of augmentation releases from an enlarged Elkhead Reservoir. The P&M Study did not use this approach. This is discussed in further detail below.



A.4.4 Environmental and Recreational

The YWG Basin evaluated the recreational and environmental needs in the YWG Basin through the P&M Study and WFET. The WFET provides series of criteria to quantitatively measure and compare environmental and recreational flow risks based on existing and modeled flow conditions in the Yampa and White Basins. This methodology is incorporated into the P&M Study to assess environmental and recreational risks associated with the P&M Study model runs.

The P&M Study specifically addresses the target at the Maybell gage for augmenting existing base flows to assist in endangered fish recovery,⁸ and instream flow shortages, and incorporates a series of risk-based ecology and flow relationship metrics to assess how current and potential future flows could impact the ecology and boating at specific locations within the YWG Basin.

Instream Flows and RICDS

The instream flows and Steamboat RICD is operated in very similar manner in the StateMod model. Figure 2-10 shows the decreed instream flows within the YWG Basin and the instream flows modeled for the P&M Study. Only 30 of the 38 decreed instream flow reaches are modeled using the existing StateMod Yampa and White models. Instream flow and RICD rights are generally administered at a designated DWR or USGS gage. StateMod simulates instream flows and RICDs using the following criteria.

- Flows are calculated at the upstream and downstream terminus of the instream flow/RICD reach as well as at each intervening structure between the two ends.
- If the instream flow/RICD is in priority, it calls out junior diversion(s) upstream of the lower terminus and the model recalculates flows.
- If the instream flow is short, but has access to storage in a reservoir, releases are made (i.e. Steamboat Lake makes late season releases to Elk River and Willow Creek).

RICD and instream flow shortages are calculated as the difference between the decreed instream flow water right and the lowest flow within the reach.

Yampa Endangered Species Fish Flow Target

The P&M Study modeled the ability to meet the instream flow targets presented in Table 2-16. When flows at Maybell were below the targeted streamflows presented in Table 2-16, up to 50 cfs was released from the 5,000 acre-feet Elkhead Reservoir storage pool to meet the monthly flow targets at Maybell. In the modeling, releases from Elkhead Reservoir are dictated by flows at Maybell. If the flow target is being met at Maybell, but not along other areas of the reach, the model did not release more water from Elkhead Reservoir even though the flows are lower at other location(s) along the reach. This is consistent with how the PBO is currently operated for existing irrigation and storage. The specific operational criteria used by the model are summarized below.

- Releases are made from Elkhead Reservoir at a rate of up to 50 cfs until the permanent 5,000 acre-feet of CWCB storage is depleted.
- The model does not release water from Elkhead Reservoir if the flow target is being met at Maybell without releases. This occurs even if an existing diversion made downstream of Maybell causes the flow somewhere within the reach to fall below the target. This consistent with the way the operations of Elkhead Reservoir are written in the Yampa PBO for existing irrigation and storage. Releases are based upon the flow targets being met at the Yampa River gage at Maybell, CO.

⁸ The P&M Study did not address the rest of the rest of the flow regime that may be necessary for endangered fish recovery on this reach of the Yampa River, on the lower Little Snake, on the Yampa River in Dinosaur National Monument, and on the Green River. These flow needs were addressed by the WFET by replicating the full flow assessment of the existing and future depletions covered by the Yampa PBO.



- The model does not include the 2,000 acre-feet pool under the long-term, renewable lease.
- The model operates in such a manner where releases from Elkhead Reservoir are not diverted by any intervening water rights within the endangered species fish flow reach.⁹
- This flow augmentation in the Yampa PBO is based on existing storage and a current depletion of 125,271 acre-feet above the Little Snake River with a projected increase in depletion of 30,104 acre feet by 2045¹⁰. The P&M Study depletions estimates and new storage above the Little Snake River are significantly higher than this. Unlike the Agricultural Water Needs Study, the P&M Study awards new water rights and assumes the perfection of conditional water rights for diversions of base flows that the PBO relied on to meet the endangered fish flow targets at Maybell. Additional information on this topic is provided in Chapter 4.

Fisheries and Cottonwood Flow-Ecology Relationship Risks

The WFET developed a series of flow-ecology metrics to measure the ecological risk associated with decreased flows in the Yampa and White Basins. These metrics were originally applied as a pilot study in the Roaring Fork and Fountain Creek watersheds and have been updated for the Yampa and White Basins. The metrics are applied to 19 nodes shown in Figure 2-11 which encompass the focus areas shown in Figure 2-9. The metrics provide a means to assess the stream's ability to support trout, warm water fish and cottonwood populations using modeled streamflows relative to the natural flows of the stream prior to human development.¹¹

Trout Flow-Ecology Relationship

This relationship compares modeled monthly flows in August and September relative to the annual natural flows. The lower the percentage of average August and September flows, the higher the risk of a particular location. The relationship estimates the ability for a stream to support trout based on the following equation:

$$\text{Trout Flow – Ecology Relationship} = \frac{\frac{\text{Mean August } Q_{\text{Existing}} + \text{Mean September } Q_{\text{Existing}}}{2}}{\text{Mean Annual } Q_{\text{natural}}}$$

Warm Water Fish Flow-Ecology Relationship

The flow-ecology metric for native bluehead sucker and flannelmouth sucker fish is represented by the following equation:

$$\% \text{ maximum native sucker potential biomass} = 0.1025 \times 30 - \text{day min flow}^{0.3021}$$

The risk associated with Warm Water Fish Flow-Ecology metric is calculated as a relative percent change from natural conditions to existing conditions. This equation below represents the relative reduction in maximum native sucker potential biomass due to the impacts of development. The greater the relative reduction in maximum native sucker potential biomass, the higher the risk.

$$\text{Warm Water Fish Flow – Ecology Relationship} = \frac{\% \text{ maximum potential biomass}_{\text{Natural}} - \% \text{ maximum potential biomass}_{\text{Existing}}}{\% \text{ maximum potential biomass}_{\text{Natural}}}$$

⁹ As storage releases decreed for instream use, such releases cannot be diverted even by senior water rights, as noted above. Senior water rights can divert the underlying base flows, but have an established pattern of historic use that was factored into the hydrologic analysis for the PBO. Diversion of the underlying base flows by new water rights would undercut the hydrologic assumptions for the PBO, however, and make it difficult to keep the PBO in place.

¹⁰ The cooperative agreement implementing the management plan for the PBO also provides: “When the first increment of depletions in Colorado [of 30,104 acre feet] approaches full development, the impacts of developing a second increment [of 20,000 acre-feet] and the status of the endangered fish species at that time will be re-evaluated pursuant to the PBO for this Agreement to implement the Management Plan.”

¹¹ Source: Arthington et al, 2006.



Cottonwood Flow-Ecology Relationship

The WFET and P&M Study refer to the “cottonwood flow-ecology” metric as the “riparian flow-ecology” metric. This metric has been renamed for purposes of the BIP to reflect that the metric exclusively assesses cottonwood as opposed to other riparian species.

The cottonwood flow-ecology metric expresses the relationship between high peak flows under natural conditions relative to modeled flow conditions in April through June. The P&M Study assessed cottonwood abundance in unconfined settings in moderate-energy confined geomorphic settings and at elevations less than 8,700 feet. The flow metric for unconfined settings is based on the change in the 90 maximum flow in wet years between current and natural flows and is expressed as:

$$\% \text{ abundance} = 1.038 \times \% \text{ flow alteration} + 1.005$$

The WFET evaluated cottonwoods for two riparian types: 1) cottonwoods on low and moderate grade, meandering unconfined rivers and 2) moderate-gradient rivers in confined valleys or high-gradient rivers in unconfined valleys. The P&M Study does not incorporate the second riparian type because the metric relies upon daily flows which are not available using the StateMod model that is based on a monthly time step. Cottonwood abundance for unconfined conditions was used as a proxy for all locations evaluated for the cottonwood flow-ecology relationship.

Each of the metrics above produce a percentage which provides means to assess the risk levels of trout, warm water fish and cottonwood riparian habitat relative to natural conditions. The WFET assigned risk levels to the range of percentages shown in Table A-6. These risk levels were developed by The Nature Conservancy and members of the YWG Basin BRT.

Table A-6 Risk Levels for the Flow-Ecology Metrics

| Metric | Low Risk | Minimal Risk | Moderate Risk | High Risk | Very High Risk |
|---|----------|--------------|---------------|-----------|----------------|
| Trout Flow - Ecology Relationship | >55% | 25% - 55% | 15% - 25% | 10% - 15% | <10% |
| Warm Water Fish Flow - Ecology Relationship | <10% | | 10% - 25% | 25% - 50% | 50% - 100% |
| Cottonwood Flow-Ecology Relationship | 0% - 15% | | 15% - 30% | 30% - 50% | 50% - 100% |

A.5 Summary of IPPs in the P&M Study

IPPs are strategies developed by water providers to assist in meeting future water supply needs that have been identified in previous studies for the YWG Basin. IPPs are grouped into the following categories:

- Permanent agricultural water transfers
- Reuse of existing fully consumable supplies
- Growth into existing supplies
- Regional in-basin projects
- New transbasin projects
- Firming in-basin water rights
- Firming transbasin water rights

The IPPs that were modeled as part of the P&M Study contained the following elements:

- Project Proponent – Acts as a source of information, i.e., reports, project stakeholder, etc.
- Location



- Physical Characteristics
- Permanent Operations
- Water Rights – Either conditional water rights, or new yet to be decreed water rights, were assumed as a proxy for new consumptive uses but not for new instream flow protection or restoration.

If the IPPs did not possess all of these elements, they were not modeled. These criteria excluded short or long-term water leases, other alternative transfer methods, and some optimized operations to avoid buying out and permanently drying up irrigated land and to improve stream flows. A summary of the IPPs modeled in the P&M Study is presented in Table A-7 below.



Table A-7 IPPs modeled in the P&M Study

| Name | Type | Description | Location | Capacity | Storage Right | Operations | Additional Source |
|--------------------------|-----------|--|----------------------------------|----------|---|---|-------------------|
| Little Bear 1 Reservoir | Reservoir | Little Bear I Reservoir was originally identified as part of the Yampa River Basin Small Reservoir Study – Phase 2 (Montgomery Watson 2000). It was one of three reservoirs carried forward from the Phase 2 study as a need was determined and upon a field visit, no fatal flaws were found. A location, capacity, and yield were determined as part of the study. | Yampa: Fortification Creek Basin | 800 AF | No conditional storage rights, junior right assumed | Releases are made to three aggregate diversions (Node ID 440511, 440612, and 440688), which were identified as the three diversions to which Little Bear I Reservoir could release water as described in the Agricultural Water Needs Study. | |
| South Fork II Reservoir | Reservoir | South Fork II Reservoir was originally identified as part of the Yampa River Basin Small Reservoir Study – Phase 2. It was one of three reservoirs carried forward from the Phase 2 study as a need was determined and upon a field visit, no fatal flaws were found. A location, capacity, and yield were determined as part of the study. | Yampa: Fortification Creek Basin | 1,700 AF | No conditional storage rights, junior storage right assumed | Releases are made to seven aggregate diversions (Node ID 440511, 440612, 440647, 440650, 440681, 440688 and 440998), which were identified as the seven diversions to which South Fork II Reservoir could release water as described in the Agricultural Water Needs Study. | |
| Monument Butte Reservoir | Reservoir | Monument Butte Reservoir was originally identified as part of the Yampa River Basin Small Reservoir Study | Yampa: Morapos Creek Basin | 4,390 AF | No conditional storage rights, junior storage right assumed | Releases are made to four aggregate diversions (Node ID 440590, 440651, 440814, and | |



| Name | Type | Description | Location | Capacity | Storage Right | Operations | Additional Source |
|-------------------|-----------|--|--|-----------|---|--|-------------------|
| | | – Phase 2 (Montgomery Watson 2000). It was one of three reservoirs carried forward from the Phase 2 study as a need was determined and upon a field visit, no fatal flaws were found. A location, capacity, and yield were determined as part of the study. | | | | aggregate diversion 44_ADY016A), which were identified as the diversions to which Monument Butte Reservoir could release water to as described in the Agricultural Water Needs Study. | |
| Rampart Reservoir | Reservoir | Rampart Reservoir was originally identified as part of the Yampa River Basin Small Reservoir Study – Phase 2. Based upon preliminary field reconnaissance and subsequent screening, Rampart Reservoir was not recommended for further analysis due to being a historical area ¹² , sediment load, extent of dam, need to relocate Highway 13, and location on federal land (Bureau of Land Management). During the October 3, 2013 subcommittee meeting, Tom Gray suggested that due diligence was recently | Yampa: Lower Fortification Creek upstream of Wisconsin Ditch | 12,133 AF | <ul style="list-style-type: none"> A first fill water right with administration number 41126.00000 and conditional storage of 12,133 AF A second fill water right with administration number 47905.00000 and conditional storage of 11,692 AF | <ul style="list-style-type: none"> Since Rampart Reservoir is only located upstream of two potentially short water diversions (the oxbows aggregate diversion and Node ID 440511), releases are made to the oxbows aggregate diversion and Node ID 440511 The second set of operations for Rampart Reservoir is to exchange water upstream to South Fork II and Little Bear I The last set of | |

¹² Fortification Rocks are a historic landmark and were used as fortresses by Native Americans.



| Name | Type | Description | Location | Capacity | Storage Right | Operations | Additional Source |
|-------------------------------|-----------|--|---|-----------|---|---|---|
| | | performed on a conditional storage right for Rampart Reservoir and that it should be considered as an IPP. | | | | operations for Rampart Reservoir is to exchange water upstream to each individual diversion on Fortification Creek | |
| Peabody Trout Creek Reservoir | Reservoir | Peabody-Trout Creek Reservoir was identified as part of a supply project to meet energy development demands for the Peabody energy development demands described in Section 3.2.1.4. Modeling for the Peabody-Trout Creek Reservoir supply project was performed by ERC. A model was received from ERC and details of the modeling were clarified through personal communications (Thompson 2013). | Yampa: Trout Creek upstream of the confluence with the Yampa River | 11,720 AF | A first fill water right with administration number 43575.00000 and conditional storage of 15,000 AF | The sole purpose of the Peabody-Trout Creek Reservoir is to meet the 6,000 AFY energy development demands (which do not have a direct diversion water right) that are also part of the Peabody-Trout Creek Project | |
| Milk Creek Reservoir | Reservoir | Details for Milk Creek Reservoir were discussed through personal communications with Tri-State Generation & Transmission Association (Chartrand 2013). Milk Creek Reservoir is part of a potential industrial supply project to meet future | Yampa: Milk Creek Reservoir upstream of the confluence with the Yampa River | 70,000 AF | <ul style="list-style-type: none"> An existing conditional water right with a 1976 date of decree of 70,000 AF; however, this is only for industrial beneficial uses. At the request of the BRT subcommittee, Milk | <ul style="list-style-type: none"> Similar to Rampart Reservoir, Milk Creek Reservoir cannot release to any water short diversions on upper Milk Creek; however, releases are made to the Yampa River oxbows | <ul style="list-style-type: none"> Additional Source – Yampa River - Milk Creek Pipeline <ul style="list-style-type: none"> The Yampa River - Milk Creek Pipeline is also part of the Milk Creek Project. The Yampa River - Milk Creek Pipeline is used to fill Milk Creek Reservoir using water from the Yampa River. |



| Name | Type | Description | Location | Capacity | Storage Right | Operations | Additional Source |
|--------------------------|-----------|---|-----------------------|----------|---|---|---|
| | | energy development demands. Although Milk Creek Reservoir currently has storage rights for industrial beneficial uses only, the BRT subcommittee requested that Milk Creek Reservoir be modeled for both industrial uses and agricultural uses. | | | <p>Creek Reservoir was modeled for agricultural and industrial uses. For the Projects and Methods Study, this conditional right maintained its 1976 water right date, but the industrial storage was reduced to 35,000 AF.</p> <ul style="list-style-type: none"> The remaining 35,000 AF of storage is filled using an undecreed water right for agricultural uses. | <p>diversion.</p> <ul style="list-style-type: none"> Milk Creek Reservoir also exchanges to all diversions upstream on Milk Creek if exchange capacity exists on the creek. No operations were defined for the industrial storage account | <ul style="list-style-type: none"> The following characteristics were determined from case number 08CW86: the pipeline has a 400 cfs conditional water right (administration number = 45923.00000). However, this water right is for industrial beneficial uses only (similar to the storage right for Milk Creek Reservoir). The pipeline water right was also split in half to fill both storage accounts (industrial and agricultural). The industrial half retained its water right seniority, but the rate was reduced to 200 cfs. The agricultural portion uses an undecreed water right also with a 200 cfs rate. |
| Morrison Creek Reservoir | Reservoir | Details for Morrison Creek Reservoir were discussed through personal communications with UYWCD through their modeling team from AMEC (Musleh 2013). The modeling approach used to include Morrison Creek | Yampa: Morrison Creek | 4,965 AF | There are two storage rights for Morrison Creek Reservoir, a first fill and a second fill. The first fill right has a 4,965 AF conditional water right (administration number = 41272.39991) and the second fill has a 5,655 AF | <ul style="list-style-type: none"> Releases to augment Stagecoach reservoir supplies Releases to Craig Releases to Walker Irrigation Ditch Releases to Mount Werner Water Releases are made | <ul style="list-style-type: none"> Additional Source – Morrison Creek Pipeline <ul style="list-style-type: none"> A 50 cfs conditional water right (administration number = 52959.00000) above Morrison Creek Reservoir was studied by the UYWCD. The modeling received from AMEC that |



| Name | Type | Description | Location | Capacity | Storage Right | Operations | Additional Source |
|------------------------|-------------|---|--|--|---|---|--|
| | | Reservoir into the Projects and Methods model was directly derived from the modeling used in the UYWCD model sent via email (dated 7/26/2013). Morrison Creek Reservoir is part of a potential supply project to meet future demands in a similar manner to Stagecoach Reservoir. | | | conditional water right (administration number = 57676.00000). | <p>to Steamboat Wells A, G, and H from the "First Fill" pool</p> <ul style="list-style-type: none"> A bypass to the Willow Spring & Pond ISF | was used in this study did not have any operations assigned and did not transfer water within the model. |
| Lake Avery Enlargement | Enlargement | The Lake Avery Enlargement was identified in the Energy Development Water Needs Assessment as part of the oil shale production supply system. The Lake Avery Enlargement is the secondary source of supply used in the oil shale production supply system (after direct diversions from the White River). | Expansion to Big Beaver Reservoir (Avery Lake) | 48,274 AF + 7,658 AF (original capacity of Big Beaver Reservoir) | <ul style="list-style-type: none"> The purpose of the Scenario 2 and 3 models of the Energy Development Water Needs Assessment was to reliably meet oil shale production demands with rights junior to all other diversions in the YWG Basin. That methodology was also used in the Projects and Methods Study. Therefore it is modeled with an undecreed water right. The Lake Avery Enlargement is filled | The only operation for the Lake Avery Enlargement is making direct releases to meet oil shale production demands | |



| Name | Type | Description | Location | Capacity | Storage Right | Operations | Additional Source |
|----------------------|-----------|---|---|------------|--|--|-------------------|
| | | | | | both by a pipeline diverting water from the White River upstream of Big Beaver Creek and a direct storage right on Big Beaver Creek. | | |
| Wolf Creek Reservoir | Reservoir | Wolf Creek Reservoir was identified in the Energy Development Water Needs Assessment as part of the oil shale production supply system. The Energy Development Water Needs Assessment recognized that under current conditions, oil shale production demands can be met using the other elements in the oil shale production supply system (Lake Avery Enlargement, Diversion from White River to fill Lake Avery, Direct Diversion from the White River (above Piceance Creek) to meet Oil Shale Demands). However, Wolf Creek Reservoir was used as an IPP in the model to demands under some of the Modeling Scenarios with drier hydrologies. | On the White River downstream of the confluence with Piceance Creek | 162,400 AF | <ul style="list-style-type: none"> The purpose of the Scenario 2 and 3 models of the Energy Development Water Needs Assessment was to reliably meet oil shale production demands with rights junior to all other diversions in the YWG Basin. That methodology was also used in the Projects and Methods Study; therefore, it is modeled with a 2013 water right. The only water right Wolf Creek Reservoir uses to store water is an undecreed water right on the White River | Water from Wolf Creek Reservoir is transported upstream via carrier to directly meet oil shale production demands. | |

